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(54) **MANIPULATOR JOINT DISPLACEMENT DETECTION MECHANISM**

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A61B 17/00 (2006.01)

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USPC **606/1**; 606/130

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USPC 606/1, 53, 79, 87, 88, 130, 138, 139; 600/101, 104, 114, 117, 118, 127, 129, 600/137; 74/490.01, 490.04–490.09
See application file for complete search history.

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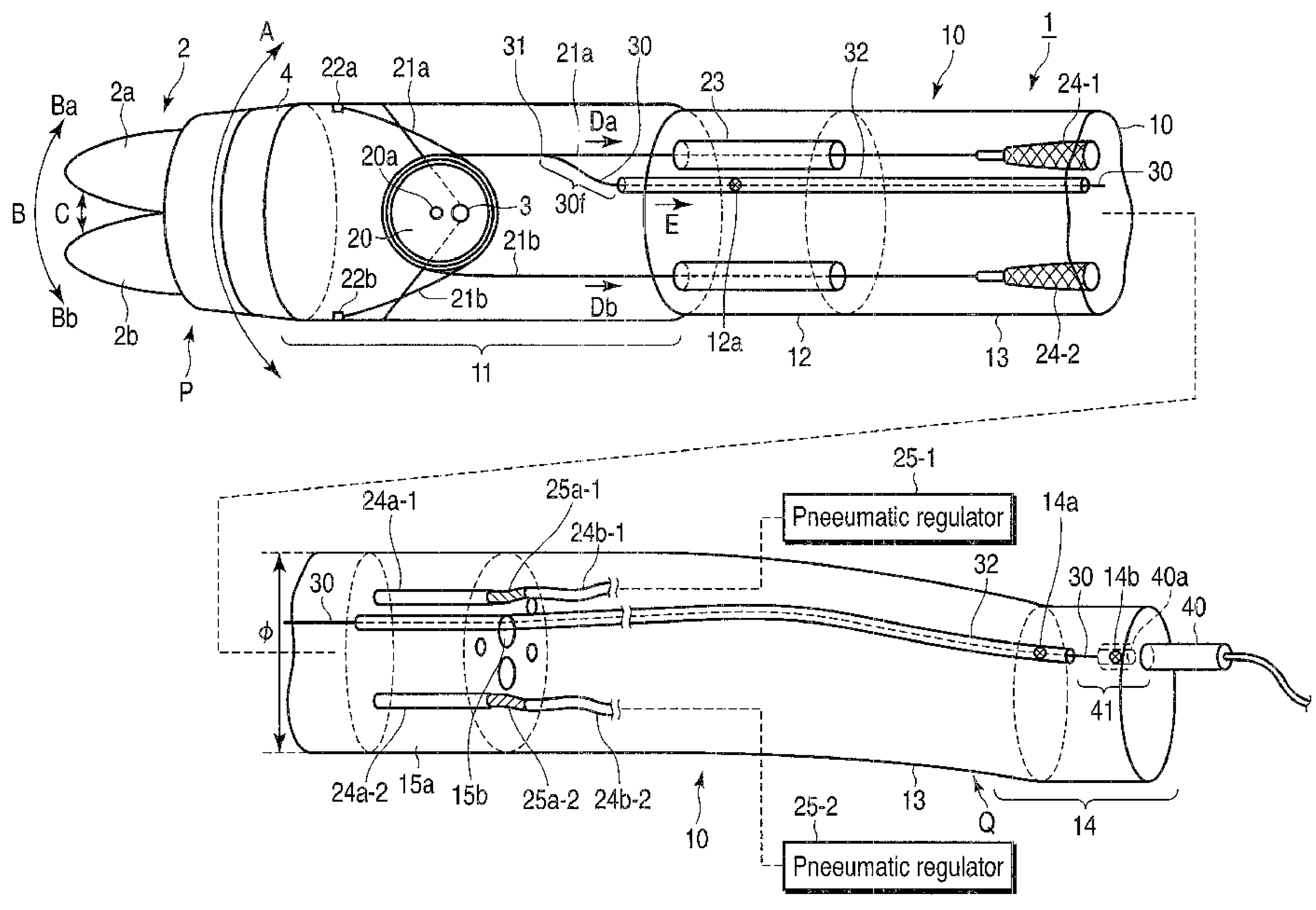
(57) **ABSTRACT**

A manipulator joint displacement detection mechanism includes a manipulator which has a actuating unit and a joint. A first transmission member is connected to the joint, and provided movably to displace the joint. A second transmission member moves corresponding to movement of the first transmission member. A guide guides movement of the second transmission member. A guide fixing part fixes one end and the other end of the guide. A sensor detects a moving distance of the second transmission member in the proximal end portion of the manipulator.

20 Claims, 1 Drawing Sheet



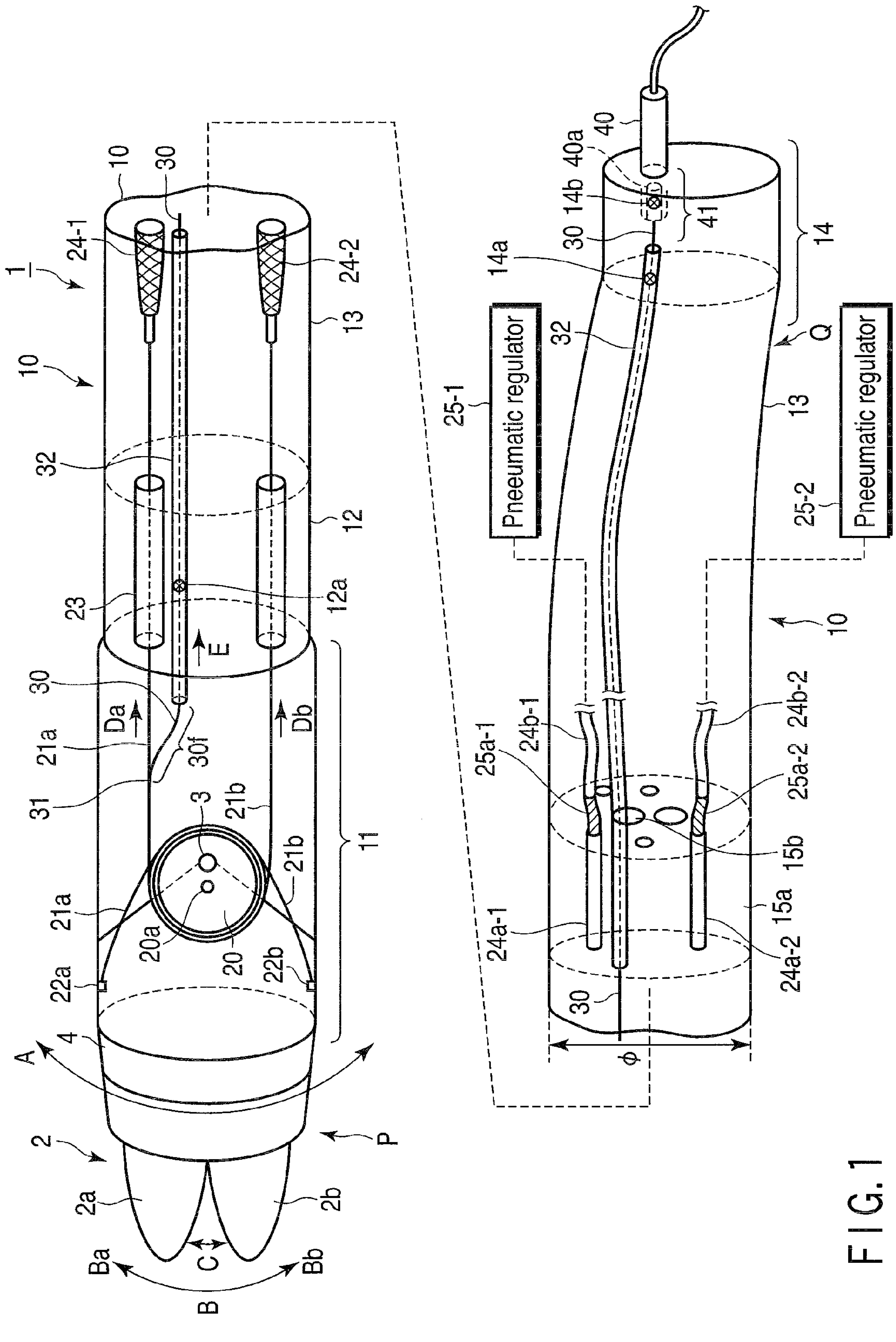

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FIG. 1

MANIPULATOR JOINT DISPLACEMENT DETECTION MECHANISM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the benefit of priority from prior Japanese Patent Application No. 2009-069059, filed Mar. 19, 2009, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a medical manipulator used for laparoscopic surgery, for example, and in particular to a manipulator joint displacement detection mechanism for detecting the degree of displacement of a joint of a manipulator.

2. Description of the Related Art

A medical manipulator is used for laparoscopic or thoracoscopic surgery. The medical manipulator is provided with a joint in the distal end portion. A joint is provided with a clutching unit equipped with a surgical instrument such as a pair of forceps. The medical manipulator transmits power of a driving source such as a motor to a joint. A member to transmit power (power transmission member) is a linear member such as a wire. A power transmission member is provided movably along a guide member inserted in the medical manipulator. A joint is displaced by the transmitted power. A clutching unit changes an angle of rotation of the pair of forceps, for example, according to displacement of a joint.

In laparoscopic or thoracoscopic surgery, a patient's abdomen is punctured, and a jig called a trocar is inserted into the puncture. A medical manipulator equipped with a surgical instrument at the distal end is inserted into the patient's abdomen through the insertion hole of the trocar. In this state, the surgical instrument of the medical manipulator is operated, and surgery is performed.

The aperture of an insertion hole of a trocar used at present is less than 10 mm in diameter. The aperture of the medical manipulator inserted into the trocar must be smaller than the aperture of the trocar. A typical medical manipulator is used in the Intuitive Surgical Corporation's Da Vinci system. The medical manipulator used in this system is formed to have a diameter of 10 mm or less, and a length of 300 mm or greater, in which a clutching unit equipped with a surgical instrument such as a pair of forceps is operated with multiple degrees of freedom.

A power transmission member of the medical manipulator uses a linear member such as a wire. Even the manipulator of the Da Vinci system uses a power transmission member such as a wire. The power transmission member is formed to have a diameter of less than 0.5 mm, for example, to transmit power in a limited space of diameter less than 10 mm.

A manipulator using a linear power transmission member having a small diameter is disclosed in U.S. Pat. No. 5,807,377, for example. This patent application discloses a technique of detecting displacement of a joint by a potentiometer or encoder placed close to a driving source such as a motor.

BRIEF SUMMARY OF THE INVENTION

According to an aspect of the invention, a manipulator joint displacement detection mechanism comprises a manipulator which includes a actuating unit and a joint, and is formed in an

elongated shape having a distal end portion and a proximal end portion, the actuating unit provided in the distal end portion, and the joint configured to displace to perform an actuating operation to the actuating unit, and transmit the displacement to the actuating unit to perform the actuating operation; a first transmission member which is connected to the joint, and provided movably to displace the joint; a second transmission member which is connected to the first transmission member in a part of the manipulator close to the joint, and is moved corresponding to a moving distance of the first transmission member; a guide which guides the movement of the second transmission member; a sensor which detects the moving distance of the second transmission member in a part close to the proximal end portion of the manipulator; a joint holder which holds the joint; a sensor holder which holds the sensor; a first guide fixing part which is provided in the joint holder, and fixes one end of the guide; and a second guide fixing part which is provided in the sensor holder, and fixes the other end of the guide.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

FIG. **1** is a diagrammatic illustration of an embodiment of a displacement detection mechanism of a manipulator joint according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

Hereinafter, an embodiment of the invention will be explained with reference to the accompanying drawing.

FIG. **1** shows a configuration of a displacement detection mechanism of a medical manipulator joint. A medical manipulator (manipulator) **1** is formed to have an elongated cylindrical shape. The manipulator includes a housing **10**, a joint **4**, and an actuating unit **2**.

The actuating unit **2** is provided in a distal end portion P of the manipulator **1**. The actuating unit **2** actuated with motion of the joint **4**. The actuating unit **2** is a clutching unit **2** such as a pair of forceps. The clutching unit **2** includes claws **2**_a_ and **2**_b_. The clutching unit clutches a diseased part by opening and closing the claws **2**_a_ and **2**_b_. The clutching unit **2** is operated with three degrees of freedom, for example. The clutching unit **2** is rotatably fixed to an axis **3**. The axis **3** is operated with one of three degrees of freedom. Operation with three degrees of freedom consists of rotation of the clutching unit **2** in the direction of arrow A about the central axis of the manipulator **1**, oscillation of the clutching unit **2** in the direction of arrow B about the axis **3**, and clutching by opening and closing of the claws **2**_a_ and **2**_b_ of the clutching unit **2** in the direction of arrow C. One joint **4** is provided for one degree of freedom. When the clutching unit **2** has three degrees of freedom, three joints **4** are provided.

In FIG. **1**, the manipulator **1** has one degree of freedom, that is, oscillation, to simplify the explanation. The housing **10** is elongated and cylindrical, and has a diameter of 10 mm, for example. The housing **10** comprises a joint holder **11**, a joint holder side guide holder (joint-side guide holder) **12**, a cylindrical unit **13**, and a sensor holder **14**, which are provided in the cylindrical interior.

The joint **4** is provided in the distal end portion of the housing **10**. The clutching unit **2** is provided at the distal end of the joint **4**. The joint **4** causes the clutching unit **2** to oscillate when displaced.

The joint holder **11** holds the joint **4**. The joint holder **11** is made of material such as SUS.

The cylindrical unit **13** is provided in the proximal end portion Q of the joint-side guide holder **12**. The cylindrical unit **13** may be made of flexible or semi-flexible material.

The manipulator **1** is integrally composed of the clutching unit **2**, the joint **4**, the joint holder **11**, the joint-side guide holder **12**, the cylindrical unit **13**, and the sensor holder **14**, from the distal end portion P to the proximal end portion Q.

A pair of pulleys **20** is rotatably provided in the joint holder **11**. The pulleys **20** are provided in parallel on the same axis of rotation. Two power transmission wires (first and second power wires) **21***a* and **21***b* are looped over the pulleys **20**. The first and second power wires **21***a* and **21***b* are required to operate with one degree of freedom. The first and second power wires **21***a* and **21***b* are wound once around the pulleys **20**. The first and second power wires **21***a* and **21***b* are made of material such as SUS.

One end of the first power wire **21***a* is fixed to the fixing part **22***a* in the joint holder **11**. One end of the second power wire **21***b* is fixed to the fixing part **22***b* in the joint holder **11**. The fixing parts **22***a* and **22***b* are provided behind the joint **4**.

The first and second power wires **21***a* and **21***b* are extended longitudinally in the housing **10**. The first and the second power wires **21***a* and **21***b* are movable axially (linear direction) in the housing **10**.

When the first power wire **21***a* is moved axially, as indicated by arrow Da, the joint **4** is pulled toward the proximal end Q of the manipulator **1**. When the first power wire **21***a* is moved in the reverse direction to arrow Da, the joint **4** is pushed to the distal end P of the manipulator **1**.

When the second power wire **21***b* is moved axially, as indicated by arrow Db, the joint **4** is pulled toward the proximal end Q of the manipulator **1**. When the second power wire **21***b* is moved in the reverse direction to arrow Db, the joint **4** is pushed to the distal end P of the manipulator **1**.

When the first power wire **21***a* is moved axially, as indicated by arrow Da, the clutching unit **2** is caused to oscillate in the direction of arrow Ba. When the second power wire **21***b* is moved axially, as indicated by arrow Db, the clutching unit **2** is caused to oscillate in the direction of arrow Bb.

The joint-side guide holder **12** connects the joint holder **11** and cylindrical unit **13**. A power guide **23** is provided in the joint-side guide holder **12**. The power guide **23** is formed a hole in the joint-side guide holder **12**. In the power guide **23**, a first power wire **21***a* is movably inserted, and guides movement of the first power wire **21***a* axially (in the direction of arrow Da and the reverse direction).

If the clutching unit **2** is operated with three degrees of freedom, two power transmission wires needed. Six power guides **23** are provided in the joint-side guide holder **12**. Six power guides **23** are provided with equal intervals on the circumference of a predetermined radius of the joint-side guide holder **12** along the longitudinal axis.

The cylindrical unit **13** connects the joint-side guide holder **12** and sensor holder **14**. The cylindrical unit **13** is formed as a cylinder.

A sensing wire guide **32** is inserted into the housing **10**. The sensing wire guide **32** is made of a tubular member, specifically a hollow tube. Hereinafter, the sensing wire guide **32** is called a sensing guide tube. The sensing guide tube **32** is provided in the joint holder **11**, the cylindrical unit **13**, and the sensor holder **14**. In the sensing guide tube **32**, a displacement sensing wire (sensing wire) **30** is movably inverted axially. The sensing guide tube **32** guides movement of the sensing wire **30**. The sensing wire **30** is moved along its own axis (linearly in the direction of arrow E and the reverse direction).

The sensing guide tube **32** has a diameter a little larger than the diameter of the sensing wire **30**. The outside diameter of the sensing guide tube **32** is 0.5 mm or less, for example. The sensing guide tube **32** is made of material to reduce friction with the sensing wire **30**. The sensing guide tube **32** is made of SUS, for example. The inside wall of the sensing guide tube **32** is polished to reduce friction with the sensing wire **30**.

One end of the sensing wire **30** is connected to the first power wire **21***a*. The sensing wire **30** transmits a moving distance of the first power wire **21***a*. A part connecting the sensing wire **30** and the first power wire **21***a* is called a connecting part **31**. The connecting part **31** is located close to the joint **4** in the sensing wire **30**. The sensing wire **30** and the first power wire **21***a* are connected by soldering or bonding. The connecting part **31** may be formed by connecting the first power wire **21***a* to one end of the sensing wire **30** with a clip-shaped member. The sensing wire **30** and the first power wire **21***a* may be connected by providing a resin connecting member with a hole, inserting the sensing wire **30** and the first power wire **21***a* into the hole, and heating the sensing wire **30** and the first power wire **21***a*.

The sensing wire **30** is made of magnetic material, such as SUS. The sensing wire **30** is formed as a thin linear wire having a diameter less than that of the first power wire **21***a*. One sensing wire **30** is connected to one first power wire **21***a*. If the clutching unit has three degrees of freedom, six sensing wires **30** are provided in the housing **10**.

The sensing wire **30** and the first power wire **21***a* are provided in parallel close to each other. The power guide **23** and the sensing guide tube **32** are provided in parallel close to each other. If the clutching unit **2** has three degrees of freedom, six tubular power guides **23** and six sensing guide tubes **32** are provided. The power guide **23** and sensing guide tube **32**, in which the connected first power wire **21***a* and sensing wire **30** are inserted, are provided in parallel close to each other.

The sensing wire **30** is exposed from the sensing guide tube **32** in the part between the connecting part **31** and one end of the sensing guide tube **32**. The exposed part of the sensing wire **30** is called a first wire exposed part **30***f*.

First and second pneumatic actuators **24-1** and **24-2** are provided in the cylindrical unit **13**. The first and second pneumatic actuators **24-1** and **24-2** constitute a driving source for causing the clutching unit **2** to oscillate, for example.

The first pneumatic actuator **24-1** is held by an actuator holder **15***a* in the cylindrical unit **13**. One end of the first pneumatic actuator **24-1** is connected to the first power wire **21***a*, and the other end of the first pneumatic actuator **24-1** is connected to a pneumatic regulator **25-1** through an actuator fluid inlet/outlet **25***a*-**1** and an actuator tube **24***b*-**1**.

The fluid inlet/outlet **25***a*-**1** is formed long enough to be inserted into the actuator holder **15***a*. The fluid inlet/outlet **25***a*-**1** is shaped like a pipe, for example. The fluid inlet/outlet **25***a*-**1** is inserted into an actuator fixing hole **24***a*-**1**. The first pneumatic actuator **24-1** is held in the actuator holder **15***a* by the fluid inlet/outlet **25***a*-**1**.

The actuator holder **15***a* is provided with an actuator holder guide through-hole **15***b*. The sensing guide tube **32** is inserted in the actuator holder through-hole **15***b*.

The first pneumatic regulator **25-1** controls the pneumatic pressure of the first pneumatic actuator **24-1**. The first pneumatic actuator **24-1** is expanded and contracted by the pneumatic pressure control. The first pneumatic actuator **24-1** contracts and moves the first power wire **21***a* axially, as indicated by arrow Da, and expands and moves the first power wire **21***a* in the reverse direction to arrow Da.

One end of the second pneumatic actuator **24-2** is connected to the second power wire **21***b*. The other end of the second pneumatic actuator **24-2** is connected to a pneumatic regulator **25-2** through an actuator fluid inlet/outlet **25***a***-2** and actuator tube **24***b***-2**.

The fluid inlet/outlet **25***a***-2** is formed long enough to be inserted into the actuator holder **15***a*. The fluid inlet/outlet **25***a***-2** is shaped like a pipe, for example. The fluid inlet/outlet **25***a***-2** is inserted into an actuator fixing hole **24***a***-2**. The second pneumatic actuator **24-2** is held in the actuator holder **15***a* by the fluid inlet/outlet **25***a***-2**.

The second pneumatic regulator **25-2** controls the pneumatic pressure of the second pneumatic actuator **24-2**. The second pneumatic actuator **24-2** is expanded and contracted by the pneumatic pressure control. The second pneumatic actuator **24-2** contracts and moves the second power wire **21***b* axially, as indicated by arrow Db, and expands and moves the second power wire **21***b* in the reverse direction to arrow Db.

One of the first and second pneumatic actuators **24-1** and **24-2** expands, the other contracts. When the first pneumatic actuator **24-1** contracts and pulls the first power wire **21***a*, the second pneumatic actuator **24-2** expands and pushes the second power wire **21***b*. When the first pneumatic actuator **24-1** expands and pushes the first power wire **21***a*, the second pneumatic actuator **24-2** contracts and pulls the second power wire **21***b*.

As a result, the clutching unit **2** receives the pulling and pushing forces of the first and second power wires **21***a* and **21***b* through the joint **4**, and oscillates in the direction of arrow B.

A driving source for displacing the clutching unit **2** is not limited to the first and second pneumatic actuators **24-1** and **24-2**. Other driving sources using a hydraulic actuator or a motor may be used.

A joint holder side guide fixing part (first guide fixing part) **12***a* is provided in the joint side guide holder **12**. The first guide fixing part **12***a* fixes the distal end of the sensing guide tube **32** to the joint-side guide holder **12**. The first guide fixing part **12***a* fixes the sensing guide tube **32** by tightening a screw through a pressure plate. Or, the first guide fixing part **12***a* fixes the sensing guide tube **32** to the joint-side guide holder **12** by bonding.

The sensor holder **14** is provided with a sensor holder side guide fixing part (second guide fixing part). The second guide fixing part **14***a* fixes the rear end of the sensing guide tube **32** to the sensor holder **14**. The second guide fixing part **14***a* fixes the sensing guide tube **32** to the sensor holder **14** by tightening a screw through a pressure plate. Or, the second guide fixing part **14***a* fixes the sensing guide tube **32** to the sensor holder **14** by bonding.

One end of the sensing guide tube **32** is fixed to the first guide fixing part **12***a* of the joint-side guide holder **12**, and the other end is fixed to the second guide fixing part **14***a* of the sensor holder **14**.

The sensor holder **14** is provided with a noncontact sensor **40**. The noncontact sensor **40** is fixed to the sensor holder **14** by the sensor fixing part **14***b*. The sensor fixing part **14***b* fixes the noncontact sensor **40** to the sensor holder **14** by tightening a screw through a pressure plate. Or, the sensor fixing part **14***b* fixes the noncontact sensor **40** to the sensor holder **14** by bonding.

The noncontact sensor **40** detects a moving distance of the sensing wire **30** in the proximal end portion Q of the manipulator **1**. The noncontact sensor **40** is a magnetic sensor, for example, and is called a magnetic sensor **40** hereinafter. As the magnetic sensor **40** is used, the sensing wire **30** is made of magnetic material such as SUS.

The sensor holder **14** is provided with a second wire exposed part **41**. In the second wire exposed part **41**, the sensing wire **30** is exposed from the sensing guide tube **32**. The magnetic sensor **40** is arranged to the wire exposed part **41**.

The magnetic sensor **40** is provided with a tubular part **40***a*. The sensing wire **30** is movably inserted in the tubular part **40***a*. In the tubular part **40***a*, the sensing wire **30** is moved along its own axis (linearly in the direction of arrow E and the reverse direction). When the sensing wire **30** is moved (displaced) in the tubular part **40***a*, the value of reactance generated between the tubular part **40***a* and sensing wire **30** is changed. The magnetic sensor **40** outputs a moving distance signal of the sensing wire **30** corresponding to the reactance value.

If the clutching unit **2** has three degrees of freedom, six magnetic sensors **40** are provided corresponding to six sensing wires **30**. Therefore, displacement in each degree of freedom of the clutching unit **2** is detected based on a moving distance of each sensing wire detected by each magnetic sensor **40**. Displacement in three degrees of freedom consists of displacement in rotation of the clutching unit **2** in the direction of arrow A about the central axis of the manipulator **1**, displacement in oscillation of the clutching unit **2** in the direction of arrow B about the axis **3**, and displacement in clutching by the clutching unit **2** in the direction of arrow C.

Next, an explanation will be given of detection of the degree of displacement of the clutching unit **2** in the apparatus configured as described above.

The first pneumatic regulator **25-1** controls the pneumatic pressure of the first pneumatic actuator **24-1**. The second pneumatic regulator **25-2** controls the pneumatic pressure of the second pneumatic actuator **24-2**. When the first pneumatic actuator **24-1** contracts and pulls the first power wire **21***a*, the second pneumatic actuator **24-2** expands and pushes the second power wire **21***b*. When the first pneumatic actuator **24-1** expands and pushes the first power wire **21***a*, the second pneumatic actuator **24-2** contracts and pulls the second power wire **21***b*. The force of pulling the first power wire **21***a* and force of pushing the second power wire **21***b*, or the force of pushing the first power wire **21***a* and force of pulling the second power wire **21***b*, are transmitted to the clutching unit **2** though the joint **4**.

As a result, the clutching unit **2** receives the pulling and pushing forces of the first and second power wires **21***a* and **21***b* through the joint **4**, and oscillates in the direction of arrow B. If the clutching unit **2** has three degrees of freedom, the clutching unit **2** rotates the manipulator **1** in the direction of arrow A about its own axis, and moves to effect clutching in the direction of arrow C, in addition to oscillating.

When the clutching unit **2** oscillates, the first pneumatic actuator **24-1** contracts, and the first power wire **21***a* moves in the axial direction indicated by arrow Da. As the sensing wire **30** is connected to the first power wire **21***a*, the sensing wire **30** moves in the axial direction indicated by arrow E in the sensing guide tube **32** corresponding to the moving distance of the first power wire **21***a*. As the friction between the sensing wire **30** and the inside wall of the sensing guide tube **32** is reduced, the sensing wire **30** moves in the sensing guide tube **32** without frictional resistance.

The moving distance of the sensing wire **30** is the same as that of the first power wire **21***a*. In other words, the sensing wire **30** moves in the sensing guide tube **32**. One end of the sensing guide tube **32** is fixed to the first guide fixing part **12***a*, and the other end is fixed to the second guide fixing part **14***a*. Therefore, even if the first power wire **21***a* expands or sags, the length of the sensing guide tube **32** is unchanged. The moving distance of the first power wire **21***a* is the same as that of the sensing wire **30**.

Therefore, the sensing wire **30** directly transmits a moving distance of the first power wire **21***a* to the magnetic sensor **40**. In other words, a moving distance of the first power wire **21***a* corresponding to the displacement caused by oscillation of the clutching unit **2** is directly transmitted to the magnetic sensor as a moving distance of the sensing wire **30**.

The magnetic sensor **40** detects a moving distance of the sensing wire **30** in the proximal end portion Q of the manipulator **1**. When the sensing wire **30** is moved (displaced) in the tubular part **40***a*, the value of reactance generated between the tubular part **40***a* and sensing wire **30** is changed. The magnetic sensor **40** outputs a moving distance signal of the sensing wire **30** corresponding to the reactance value. According to the moving distance signal from the magnetic sensor **40**, the displacement of the joint **4** caused by oscillation of the clutching unit is determined.

If the clutching unit **2** has three degrees of freedom, six sensing wires **30** are provided in the housing **10**. Six magnetic sensors **40** are provided for six sensing wires **30**. Displacement of the joint **4** in each degree of freedom of the clutching unit **2** is detected based on the moving distance signals from six magnetic sensors **40**. Displacement of the joint **4** in three degrees of freedom consists of displacement in rotation of the clutching unit **2** in the direction of arrow A about its own axis, displacement in oscillation of the clutching unit **2** in the direction of arrow B about the axis **3**, and displacement in clutching by the clutching unit **2** in the direction of arrow C.

As descried above, an embodiment of the invention comprises a sensing wire **30** which transmits a moving distance of a first power wire **21***a*; a sensing guide tube **32** which guides movement of the sensing wire **30**; a magnetic sensor **40** which detects a moving distance of the sensing wire **30** in a proximal end portion Q of a manipulator **1**; a joint holder **11** which holds a joint **4**; a sensor holder **14** which holds a magnetic sensor **40**; a joint-side guide holder **12** which fixes one end of the sensing guide tube **32**; and a sensor holder side guide fixing part **14***a* which fixes the other end of the sensing guide tube **32**. In this configuration, displacement of the joint **4** can be precisely detected in an area close to the joint **4** without increasing the diameter of the manipulator **1**.

Since the sensing guide tube **32** is fixed to the first and second guide fixing parts **12***a* and **14***a*, even if the first power wire **21***a* expands or sags, the length of the sensing guide tube **32** is unchanged. As one of the sensing wire **30** is connected to the first power wire **21***a* in the area close to the joint **4**, the sensing wire **30** is hardly affected by expansion or sag of the first power wire **21***a*.

Since the sensing wire **30** is connected to the first power wire **21***a* in the area close to the joint **4**, and is not subjected to a stress for transmitting power, the sensing wire **30** is not affected by expansion or sag of the first power wire **21***a*.

Since the sensing wire **30** is not subjected to a stress for transmitting power, the sensing wire **30** may be made of a member having a diameter less than that of the first power wire **21***a*. The sensing wire **30** may be provided in a limited space having a diameter of less than 10 mm in the manipulator **1**. The apparatus can precisely detect the degree of displacement of the joint **4** without increasing the diameter of the manipulator **1**. The apparatus can detect a moving distance of the clutching unit **2** provided in the distal end portion P of the manipulator **1** more precisely than a conventional apparatus without increasing the diameter of the manipulator **1**.

An electrical part such as a potentiometer and encoder is not used in proximity to the joint **4**. The apparatus is hardly affected by heat and pressure, and detection of displacement of the joint **4** is not affected, even when the apparatus is sterilized.

Therefore, the apparatus can detect the degree of displacement of the joint **4** more precisely than is the case in an area close to a driving source comprising first and second pneumatic regulators **25-1** and **25-2** as in a conventional apparatus. The apparatus can precisely detect movement of the clutching unit **2** provided in the distal end portion P ahead of the joint **4**.

Since the sensing wire **30** is formed smaller in diameter than the first power wire **21***a*, the sensing wire **30** can be provided in a limited space having a diameter of less than 10 mm in the housing **10**. The apparatus can detect movement of the clutching unit **2** provided in the distal end portion P ahead of the joint **4** more precisely than a conventional apparatus without increasing the diameter of the manipulator **1**.

Since the magnetic sensor **40** is of a noncontact type, it does not contact the sensing wire **30**, and detects a moving distance of the sensing wire **30**, without affecting movement of the sensing wire **30**. The apparatus can precisely detect displacement of the joint **4** according to a moving distance of the sensing wire **30**, and can detect movement of the clutching unit **2** more precisely.

The sensing wire **30** is guided throughout its length by the sensing guide tube **32** along the cylindrical housing **10**. Therefore, the sensing wire **30** responds to displacement of the first power wire **21***a*, and moves by the same moving distance as that of the first power wire **21***a*. As a result, the apparatus can precisely detect displacement of the joint **4**, and can detect movement of the clutching unit **2** more precisely.

The sensing guide tube **32** is formed tubular to insert the sensing wire **30**. Since the sensing guide tube **32** guides the movement all around the sensing wire **30**, the movement of the sensing wire **30** can be reliably guided.

The joint-side guide holder **12** comprises a power guide **23** to guide movement of the first power wire **21***a*, and a first fixing part **12***a* to fix the distal end of the sensing guide **32**. This simplifies the configuration of the apparatus.

Between the connecting part **31** and joint-side first guide fixing part **12***a*, a joint-side exposed part is provided to expose the sensing wire **30** from the sensing guide tube **32**. Even if a moving distance of the first power wire **21***a* is increased, the connecting part **31** does not interfere with the sensing guide tube **32**. Movement of the first power wire **21***a* is precisely transmitted to the sensing wire **30**.

The sensing guide tube **32** is provided in the housing **10** to movably guide the sensing wire **30**. Therefore, the sensing wire **30** hardly sags, and the sensing wire **30** inserted into the sensing guide tube is placed in the housing in parallel with the first power wire **21***a*. A movement course of the first power wire **21***a* and sensing wire **30** are placed close to each other. As a result, the sensing wire **30** can precisely transmit the displacement of the joint **4** to the magnetic sensor **40**.

In the housing **10**, the joint-side guide holder **12** and at least a part of the proximal end portion Q of the manipulator **1**, for example, the cylindrical unit **13**, are made of flexible or semi-flexible material. Therefore, displacement of the joint **4** is detected in the joint **4** rather than in the first guide fixing part **12***a*. Even if at least a part of the proximal end portion Q of the manipulator **1** behind the first guide fixing part **12***a* is flexible or semi-flexible, displacement of the joint **4** can be detected. Movement of the clutching unit **2** can be precisely detected.

Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

In the embodiment described above, the actuating unit is the clutching unit **2**, such as a pair of forceps. The actuating unit may be anything that can be operated by the joint **4**, for example, a surgical instrument such as a pair of scissors or a surgical knife.

In the embodiment described above, the entire length of the housing **10** and sensing guide tube **32** are made of hard material, such as SUS. The rear end side of the joint-side guide holder **12** may be made of flexible or semi-flexible material. In this case, as the displacement of the joint **4** is detected in a part close to the joint **4** ahead of the joint-side guide holder **12**, movement of the clutching unit **2** can be precisely detected. Even if the sensing guide tube **32** is made of SUS, it can be bent by making the wall thickness 0.1 mm. Therefore, even if the housing **10** is made of flexible or semi-flexible material, displacement of the joint **4** can be detected.

Connection between the first power wire **21***a* and sensing wire **30** is completed by connecting the first power wire **21***a* to one end of the sensing wire **30**, inserting the connected first power wire **21***a* into the power guide **23** of the joint-side guide holder **12**, and inserting the sensing wire **30** into the sensing wire guide tube **32** fixed to the joint-side first guide fixing part **12***a* of the joint-side guide holder **12**. Therefore, the housing **10** may be configured as one unit with the joint holder **11**, the joint-side guide holder **12**, and the cylindrical unit **13**.

In the above embodiment, a tubular member is used for the sensing guide tube **32**, which slidably guides the sensing wire **30** along movement of the first power wire **21***a*. The sensing guide tube **32** may be a guide member having an arc-shaped cross section, for example. In this case, a sensing guide tube is fixed by bonding, not by using a screw.

In the above embodiment, a fixing part of the sensing guide tube **32**, which guides the first power wire **21***a*, and the power guide **23**, are provided in the joint-side guide holder **12** that is one of the constituent elements. The fixing part of the sensing guide tube **32** and the power guide **23** may be provided at different positions along the length of the housing **10**.

In the above embodiment, a noncontact magnetic sensor **40** is used, but an optical sensor may be used. When an optical sensor is used, the sensing wire **30** is made of Ni—Ti, for example, a slit of desired length is provided in an end portion exposed from the sensing guide tube **32**, an optical fiber is provided opposing the slit, and the light reflected from the optical fiber is detected, thereby detecting a moving distance of the sensing wire **30**.

A contact-type sensor may be used. In this case, a linear member made of SUS is additionally fixed to the distal end of the sensing wire **30** made of Ni—Ti, and a conductive needle is brought into contact with the SUS linear member, and a potential difference caused by movement of the linear member is measured, thereby detecting a moving distance. Friction between the needle and linear member is preferably as small as possible.

In the above embodiment, the manipulator **1** has three degrees of freedom. A manipulator may have one degree of freedom. A driving source is not limited to a pneumatic actuator. A driving source may be a hydraulic or oil hydraulic actuator, or a motor.

What is claimed is:

1. A manipulator joint displacement detection mechanism comprising:

a manipulator which includes an actuating unit and

a joint, and is formed in an elongated shape having a distal end portion and a proximal end portion,

the actuating unit provided in the distal end portion, and the joint configured to displace to perform an actuating operation to the actuating unit, and transmit the displacement to the actuating unit to perform the actuating operation;

a first transmission member which is connected to the joint, and provided movably to displace the joint;

a second transmission member which is connected to the first transmission member in a part of the manipulator close to the joint, and is moved corresponding to a moving distance of the first transmission member;

a guide which guides the movement of the second transmission member, the guide comprising a first end and a second end;

a sensor which detects the moving distance of the second transmission member in a part close to the proximal end portion of the manipulator;

a joint holder which holds the joint;

a sensor holder which holds the sensor;

a first guide fixing part which is provided in the joint holder, and fixes the first end of the guide; and

a second guide fixing part which is provided in the sensor holder, and fixes the second end of the guide.

2. The manipulator joint displacement detection mechanism according to claim **1**, wherein the guide is formed in a tubular shape, in which the second transmission member is inserted.

3. The manipulator joint displacement detection mechanism according to claim **1**, further comprising:

a connecting part which connects the first and second transmission members,

wherein the second transmission member has a first exposed part which is exposed from the guide between the connecting part and the first guide fixing part.

4. The manipulator joint displacement detection mechanism according to claim **1**, further comprising:

a cylindrical housing which is provided between the first guide fixing part and the second guide fixing part,

wherein the housing houses at least the first transmission member, the guide, and the second transmission member.

5. The manipulator joint displacement detection mechanism according to claim **4**, wherein the housing and the guide are made of flexible or semi-flexible member in a part between the first guide fixing part and the proximal end portion of the manipulator.

6. The manipulator joint displacement detection mechanism according to claim **1**, wherein the sensor includes a noncontact sensor.

7. The manipulator joint displacement detection mechanism according to claim **6**, wherein the sensor includes a magnetic sensor.

8. The manipulator joint displacement detection mechanism according to claim **1**,

wherein the second transmission member has a second exposed part which is exposed from the guide within the sensor holder, and

the sensor is provided in the second exposed part.

9. The manipulator joint displacement detection mechanism according to claim **1**, wherein the second transmission member is formed to be thinner than the first transmission member.

10. The manipulator joint displacement detection mechanism according to claim **9**, wherein the second transmission member is formed in a linear shape.

11. The manipulator joint displacement detection mechanism according to claim **1**,

wherein the first transmission member includes a first wire, the second transmission member includes a second wire, and

the diameter of the second wire is less than the diameter of the first wire.

12. The manipulator joint displacement detection mechanism according to claim **1**, wherein the second wire moves the same moving distance as the moving distance of the first wire.

13. A manipulator joint displacement detection mechanism comprising:

a manipulator which includes a actuating unit and a joint, and is formed in an elongate shape having a distal end portion and a proximal end portion,

the actuating unit provided in the distal end portion, and

the joint configured to displace to perform an actuating operation to the actuating unit, and transmit the displacement to the actuating unit to perform the actuating operation;

a first transmission member which is connected to the joint, and provided movably to displace the joint;

a second transmission member which moves corresponding to movement of the first transmission member;

a guide which guides movement of the second transmission member, the guide comprising a first end and a second end;

a guide fixing part which fixes the first end and the second end of the guide; and

a sensor which detects a moving distance of the second transmission member in the proximal end portion of the manipulator.

14. The manipulator joint displacement detection mechanism according to claim **13**, wherein the guide is formed in a tubular shape, in which the second transmission member is inserted.

15. The manipulator joint displacement detection mechanism according to claim **13**, wherein the sensor includes a noncontact sensor.

16. The manipulator joint displacement detection mechanism according to claim **15**, wherein the sensor includes a magnetic sensor.

17. The manipulator joint displacement detection mechanism according to claim **13**, wherein the second transmission member is formed to be thinner than the first transmission member.

18. The manipulator joint displacement detection mechanism according to claim **17**, wherein the second transmission member is formed in a linear shape.

19. The manipulator joint displacement detection mechanism according to claim **13**,

wherein the first transmission member includes a first wire,

the second transmission member includes a second wire, and

the diameter of the second wire is less than the diameter of the first wire.

20. The manipulator joint displacement detection mechanism according to claim **19**, wherein the second wire moves the same moving distance as the moving distance of the first wire.

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